

RESPONSE TO COMMENTS ON  
DRAFT FINAL PROJECT WORK PLAN  
REVISION 0, MAY 27, 2005  
PCB HOT SPOT SOIL EXCAVATION SITE  
PARCELS E AND E-2, HUNTERS POINT SHIPYARD  
SAN FRANCISCO, CALIFORNIA

Comments dated: October 31, 2005

Comments by: Tom Lanphar  
Department of Toxic Substances Control (DTSC)

**Comment 1:** *Thank you for the opportunity to review the draft final Project Work Plan for the PCB Hot Spot Time Critical Removal Action. DTSC appreciates the modifications the Navy has made to the work plan especially the activities to better characterize the post removal action chemical and radiological contamination within the excavation area.*

*The scope of the removal action has changed to include the removal of PCB contaminated soil from IR-02 under the PCB Hot Spot TCRA. This modification does not appear to be included in the work plan. Please include a description of the additional PCB contaminated soil from IR-02 is included in the TCRA in the appropriate section of the final work plan. We have no further comments at this time.*

**Response 1:** The removal of the subject PCB spots will be executed under the PCB Hot Spot project and is outlined in a field change request (FCR-PCBHS-030). By allowing PCB Hot Spot to receive and screen the PCB contaminated soils, the creation of an additional waste stream under the IR-02 Northwest and Central project is avoided. The soils will be handled using the same protocol as the soils excavated from the PCB Hot Spot area and eventually characterized for waste disposal purposes and disposed of with the other PCB contaminated soils. The information in the FCR will be incorporated into the Final version of the work plan for PCB Hot Spot.

An excerpt from FCR-PCBHS-030 reads as follows:

“The PCB Hot Spot Soil Excavation Site project (CTO 84) includes removal of PCB contaminated soil to defined lateral and vertical removal action objectives. According to historical data, the PCB concentration in the grid 69 boring in IR-02 Northwest and Central is 110 ppm at 3.00 feet (ft) below ground surface (bgs), and in grid 103, 490 ppm at 2.75 ft bgs. Both borings contain PCB concentrations greater than 100 ppm and will therefore be removed to comply with

Code of Federal Regulations, Part 761, Disposal of PCBs; Final Rule. The PCB Hot Spot excavation area will be expanded to include removal of the PCB hot spots within the IR-02 Northwest and Central excavation boundary, as it is set up to survey, handle and dispose of PCB contaminated soils. The soil will be scanned for radioactive contamination per FCR-IR02-018 (covering the surveying of soils directly in the excavator bucket prior to being removed from the excavation location), analyzed, processed and disposed of as outlined the PCB Hot Spot Soil Excavation Site Work Plan.”

**RESPONSE TO COMMENTS ON  
FIELD CHANGE REQUEST 035 (FCR-PCBHS-035)  
SEPTEMBER 2005  
PCB HOT SPOT SOIL EXCAVATION SITE  
PARCELS E AND E-2, HUNTERS POINT SHIPYARD  
SAN FRANCISCO, CALIFORNIA**

Comments dated: September 13, 2005

Comments by: Michael Work  
Superfund Division (SFD-8-3)  
U.S. Environmental Protection Agency (EPA)

**Comment 1:** *Section 5.14.2, Mass Excavation: It is possible that some of the containers that are spread out on the pad may be corrosive or otherwise incompatible with the 20-mil HDPE or PVC liner. It is recommended that solid polyethylene trays be used to construct the pad to contain liquids.*

*In addition, if the containers break and liquids pool, chemical reactions may occur. It may not be appropriate to pump pooled liquids from the pad. Protocols for addressing the potential for minimizing this potential or for addressing chemical reactions should they occur should be included.*

**Response 1:** HDPE (high density polyethylene) and PVC (polyvinyl chloride) liners are considered very durable materials for the application. The majority of the volume of liquids possibly coming into contact with the liner are oily materials and both HDPE and PVC has a very good oil (hydrocarbon) resistance (e.g. 20-mil HDPE liner has 98 percent of its strength retained after 30 days of immersion (ASTM D471)). The main compatibility concern is organic liquids/pure solvents; however, during the cleanup activities, materials will only be in contact with the liner for a short period of time. In addition, high concentrations of liquids will be diluted by the presence of soil and therefore the ability of reacting with the protective liner is reduced. Liner materials used will be inspected prior to use and if affected, the liner will be replaced.

The text was revised to provide the option of using solid polyethylene trays in the event large deteriorated drums/containers are discovered to facilitate better means of retaining liquids.

**Comment 2:** *Section 5.14.5, Special Handling: The text states that drums will be taken to an "upwind staging and sampling area," but this would result in potential exposure of anyone downwind, so it appears that the text*

*should state that drums will be taken to a "downwind staging and sampling area."*

**Response 2:**

The staging and sampling area will be located upwind. Windrose data shows that the wind direction at PCB Hot Spot predominantly is to the east. If a downwind area for handling was to be identified, it would have to be located outside the excavation boundary to not affect workers in the stockpile area. As unnecessary handling (movement) of drums and containers with unknown chemical substances should be avoided and materials cannot be moved outside the excavation boundary, temporary staging and sampling is proposed to take place adjacent and upwind to the actual burial site. A safe downwind distance for workers from the actual excavation of drums, bottles, jars and containers has been established (greater than 150 feet) and, not to compromise this distance, any special handling will take place upwind of the excavation.

**Comment 3:**

*Section 5.14.5.2, Bulging Containers: The text indicates that "openings into pressurized drums will be plugged," but this may create explosive conditions. Please verify that this is correct.*

**Response 3:**

Plugging of pressurized drums will be performed with the intent to release pressure by using pressure venting caps. In this way, explosive conditions can be avoided. The sentence in Section 5.14.5.2 reads: "....will be plugged and ... ..fitted with pressure venting caps...". If pressurized containers are identified, they will be safely stored temporarily outdoors to avoid any gases accumulation in an enclosed area. A specialized gas cylinder and disposal subcontractor will be called to handle containers with pressurized content.

**Comment 4:**

*Section 5.14.5.6, Air Reactive Wastes: The text only indicates that materials suspected to be air reactive substances will be segregated and transported to a separate high hazard interim storage and disposal area, but does not include provision for problems that may occur when such materials are exposed to air. For example, clean sand could be used to smother flammable materials, if sand was on hand at the materials handling area. Please briefly discuss provisions for dealing with air reactive wastes that are exposed to air.*

**Response 4:**

Air reactive wastes will be HazCat analyzed for identification and stored under water or other appropriate liquid to minimize contact with air. HazCat analyses will follow appropriate procedures and Activity Hazard Analysis documents will be available. Section 5.14.4.6 was supplemented with the following text: "If conditions become reactive, clean sand can be used to smother flammable materials."

**Comment 5:**

*Disposal of these materials is not addressed in the work change order, so it is unclear if incineration will be considered to destroy some of*

*these unknown materials. Please clarify if incineration will be considered as a disposal option.*

**Response 5:**

Disposal of chemical materials will be carried out in accordance with the Waste Management Plan (Section 7.0) included in the Work Plan. Incineration will most likely be the most appropriate disposal option. HazCat analyses will be performed to determine appropriate handling and storage conditions and facilitate any possible waste consolidation.

**RESPONSE TO COMMENTS ON  
FIELD CHANGE REQUEST 035 (FCR-PCBHS-035)  
SEPTEMBER 2005  
PCB HOT SPOT SOIL EXCAVATION SITE  
PARCELS E AND E-2, HUNTERS POINT SHIPYARD  
SAN FRANCISCO, CALIFORNIA**

Comments dated: September 14, 2005

Comments by: Michael Work  
Superfund Division (SFD-8-3)  
U.S. Environmental Protection Agency (EPA)

**Comment 1:** *It is unclear to EPA why some anomalies were not selected for further evaluation. It is unclear to EPA why some anomalies were not selected for further evaluation. For example, the signature of the anomalies that extend from the southeastern portion of grid square 88 into the northwestern and southern portions of grid square 79 is similar to some of the other anomalies (e.g., E1 and E6) that will be investigated. It seems unlikely that the signatures in these areas are attributable only to the mapped surface features, so it is recommended that these areas also be investigated by trenching.*

**Response 1:** The intent of the geophysical survey at PCB Hot Spot was to generate information to be used to predict additional burial areas/sites within the excavation boundary. This will allow for the field crew to be informed and take the appropriate precautions prior to the unearthing of drums, bottles and containers with unknown chemical substances. The geophysical survey data generated several suspect areas, of which seven were selected for further potholing for validation of the interpreted results. The basis for selecting the seven areas/ellipses for potholing was that they were representative areas and that they each generated different types of characteristic readings and geophysical responses. By unearthing the selected seven representative areas, the survey responses can be matched up with the actual material in the ground. In this way, parallel predictions for the other areas with similar responses can also be made confidently ahead of time without having to pothole all suspect responses prior to the excavation of the whole area.

**RESPONSE TO COMMENTS ON  
FIELD CHANGE REQUEST 035 (FCR-PCBHS-035)  
SEPTEMBER 2005  
PCB HOT SPOT SOIL EXCAVATION SITE  
PARCELS E AND E-2, HUNTERS POINT SHIPYARD  
SAN FRANCISCO, CALIFORNIA**

Comments dated: September 23, 2005

Comments by: Michael Work  
Superfund Division (SFD-8-3)  
U.S. Environmental Protection Agency (EPA)

**Comment 1:** *Response to Comment 1 (dated September 13, 2005): The response does not fully consider the potential incompatibility of 20-mil high density polyethylene (HDPE) or polyvinyl chloride (PVC) liners with pure solvents or some acids. It suggests that if these materials are only in contact with the liner for a short time problems will not occur, but evidence to show that the liners would not breach in a short period of time was not included. It is also not clear how a spill, if it occurred, would be cleaned up in a short time. Please provide the BCT with the manufacturer's liner compatibility data. Also, at a minimum, the liners should be inspected for evidence of breaches (e.g., breaks, bubbles, or distortion) on a frequent basis. Since the response indicates that the option of using solid polyethylene trays has been added to the Change Order, if liner breaches are observed, the field team could switch from using 20-mil HDPE or PVC liners to solid trays. Further, this response did not address whether it would be appropriate to pump pooled liquids if chemical reactions occur or provide any indication of actions that would be taken if chemical reactions do occur. Please recommend that the HDPE or PVC liners be inspected frequently and that if any evidence that the liner integrity has been compromised is observed, that solid polyethylene trays be substituted for the liner. In addition, ways to identify chemical reactions and actions to be taken if those reactions occur should be discussed in the text of the change order.*

**Response 1:** The majority of the intact and/or deteriorated drums encountered at PCB Hot Spot have contained petroleum oils and grease. A few drums have contained gasoline. Hazcat analysis has shown that acids, bases, solvents and organic salts (laboratory chemicals) have been present in smaller volumes in bottles and smaller containers. As stated in the field change request (FCR-PCBHS-035), the liner will be placed right next to the specific burial site (i.e. within the excavation boundary containing PCB and TPH contaminated soils) to protect against liquids leaking from deteriorated containers and further contaminate the soil

during the recovery activity. If a spill would occur, absorbent materials and/or soil will be mixed in with the liquid to prevent the liquid from escaping. This will also facilitate dilution of concentrated liquids and easy collection with shovels or smaller equipment. Containers will be over-packed and associated contaminated soil will be segregated for waste characterization prior to disposal.

The 20-mil liner typically used at PCB Hot Spot is made of polyvinyl chloride (PVC). A report showing chemical resistance of PVC to organic compounds and extremely acidic and alkaline conditions is attached to confirm compatibility (Reference; T. A. Ranney, L. V. Parker, *Susceptibility of ABS, FEP, FRE, FRP, PTFE and PVC Well Casings to Degradation by Chemicals*, US Army Environmental Center, Aberdeen Proving Ground, Maryland, January 1995). In this study PVC was evaluated for changes in weight and signs of physical degradation. The results show that acetic acid, hydrochloric acid (25% w/v), sodium hydroxide (25% w/v), benzyl and methyl alcohol, gasoline, hexane and kerosene and carbon tetrachloride had little or no effect on PVC, even after a long contact time (up to 112 days). The study also showed that PVC was susceptible to degradation by acetone, benzaldehyde, chloroform, 1,2-dichloroethane, methyl ethyl ketone, methylene chloride and nitro benzene, indicating that PVC is especially susceptible to neat polar, non-hydrogen-bonded solvents. Given the fact that the drums and containers uncovered at PCB Hot Spot contain blends of waste oils/liquids and greases opposed to neat solvents of high concentrations, the 20-mil PVC liner is considered appropriate to be used as a temporary barrier during excavation of unknown chemicals.

The liner will be inspected for evidence of breaches on a frequent basis. The subject FCR also outlines that if the liner integrity has been compromised, solid trays will be used. Based on the intent to apply absorbent materials or soil onto liquids, pooled liquids that need to be pumped into a container are not expected to be generated. Also, high concentrations of liquids will be diluted by the presence of soil and therefore the ability of reacting is significantly reduced. In the event pooled liquids would be generated and a chemical reaction would occur, the field crew will follow OSHA guidelines regarding identification and actions to be taken. The Basewide Health and Safety Plan and the Site-specific Health and Safety Plan govern the procedures to be applied.

**Comment 2:**

*Response to Comment 2 (dated September 13, 2005): The response does not state that the fact that site workers will be in Level B respiratory protection allows use of an upwind staging area for drums and containers. Since the Base Realignment and Closure (BRAC) Cleanup Team (BCT) was informed that work would be conducted in*



*Level B, it appears that use of an upwind staging and sampling area is not an issue for the polychlorinated biphenyl (PCB) Hotspot Area, but the IR-02 excavation area is adjacent to and downwind of the PCB Hotspot Area and workers in this area could also be impacted. Since the IR-02 excavation is adjacent to and downwind of the PCB Hotspot area and IR-02 workers do not wear respiratory protection, continuous or frequent breathing zone monitoring for volatile organic compounds should be implemented at the upwind edge of IR-02.*

**Response 2:**

FCR-PCBHS-035 (and the Final PCB Hot Spot Soil Excavation Site Work Plan) states in Section 5.14.1 that site workers will be in Level B PPE, which includes supplied air.

The predominant wind direction at PCB Hot Spot and IR-02 Northwest and Central is eastern (see Windrose data attached). This ensures that the likelihood of IR-02 Northwest and Central being impacted during excavation of containers with unknown content is very small. A 150-foot downwind safety distance has also been established for site workers that are not wearing Level B PPE, independently of the TCRA-site that they are working on. The Site-specific Health and Safety Plan outlines the monitoring requirements for volatile organic compounds for the removal action. When it became clear that PCB Hot Spot contained drums and containers with unknown chemical substances, the personal air-monitoring requirements were reconsidered. Consequently, FIDs are now used as well as PIDs for organic compounds monitoring.

**RESPONSE TO COMMENTS ON  
FINAL PROJECT WORK PLAN  
REVISION 0, NOVEMBER 10, 2005  
PCB HOT SPOT SOIL EXCAVATION SITE  
PARCELS E AND E-2, HUNTERS POINT SHIPYARD  
SAN FRANCISCO, CALIFORNIA**

Comments dated: November 30, 2005

Comments by: Michael Work  
Superfund Division (SFD-8-3)  
U.S. Environmental Protection Agency (EPA)

**Comment 1:** *Section 5.14, Buried Drums, Bottles, Jars and Containers with Unknown Content: While reviewing the insert pages for the Final Project Work Plan, PCB Hot Spot Soil Excavation Site, Parcels E and E-2, we identified the following potential "new" issue.*

*We know that at least one drum that contained VOCs, pesticides, and PCBs, was punctured during excavation and that some or all of the contents were released to the ground; we have also know that some of the other drums were not intact (as of a couple of weeks ago, we had over-packed 93 drums).*

*The issue is this: it appears that the post-excavation confirmation sampling does not include VOCs or SVOCs, which are likely present in some of the drums. Since some drums are known to have leaked, soil was likely contaminated, so therefore, it would seem necessary that the post-excavation sampling include all of the constituents that were disposed of in the drums.*

**Response 1:** When the drum burial area was encountered in grids 88 and 89, volatile hydrocarbons (VOC) were the first compounds measured for in the field using a PID. During those measurements, no VOCs were identified. The laboratory analyses run on the punctured drum were selected with the objective to identify its content from a health and safety point out of concern for site-workers. The laboratory analyses included total petroleum hydrocarbons (TPH) including gasoline, extractable hydrocarbons and purgeable organics, organochlorine pesticides, PCBs, potassium and phosphorous. Evaluation of the results showed that the drum contained petroleum oils, PCBs and some pesticides.

With this information at hand, post-excavation sampling of grids 88 and 89 will include an expanded suite of chemical analysis. In addition to the currently established sampling protocol including PCB,

TPH and radionuclides of concern, soil samples from the bottom of the excavation will also be analyzed for VOCs, SVOC and organochlorine pesticides. A field change notice and/or a Sampling and Analysis Plan Addendum will be developed to include these analyses in the work plan.

F: (713) 674-4444

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# SPECIAL REPORT 95-1

## Susceptibility of ABS, FEP, FRE, FRP, PTFE, and PVC Well Casing to Degradation by Chemicals

Thomas A. Ranney and Louise V. Parker

January 1995

**Abstract**

This study compares the chemical resistance of four less commonly used materials for casing groundwater monitoring wells: acrylonitrile butadiene styrene (ABS), fluorinated ethylene propylene (FEP), fiberglass-reinforced epoxy (FRE), and fiberglass-reinforced plastic (FRP), with two more commonly used casing materials: polyvinyl chloride (PVC) and polytetrafluoroethylene (PTFE). The six materials were exposed to 28 neat organic compounds (including one acid) and to extremely acidic and alkaline conditions for up to 112 days. This was done to simulate some of the most aggressive environments that monitoring well casings may be exposed to. The casings were observed for changes in weight and signs of physical degradation (swelling, softening, decrease in strength, deterioration, or dissolution). As expected, the two fluorinated polymers (FEP and PTFE) were the most inert materials tested. They were not degraded by any of the test chemicals, although samples exposed to a few organic chemicals did show a slight weight gain (~1%). Among the nonfluorinated products tested, FRE was the most inert. Three organic chemicals caused particles to flake from the FRE surface, followed by separation of the glass fibers, and two organic chemicals caused weight gains exceeding 10%. Also, highly acidic conditions (pH < 1) degraded this material, and this may limit the use of this material in acidic environments. ABS was the most readily degraded material. By the end of the study, only the acid and alkaline solutions had little effect on ABS. FRP was more severely degraded by the organic chemicals than FRE was, but was less affected than PVC. Like FRE, FRP was also degraded under highly acidic conditions.

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380-89a, *Standard Practice for Use of the International System of Units*, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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# Special Report 95-1



**US Army Corps  
of Engineers**

Cold Regions Research &  
Engineering Laboratory

## **Susceptibility of ABS, FEP, FRE, FRP, PTFE, and PVC Well Casing to Degradation by Chemicals**

Thomas A. Ranney and Louise V. Parker

January 1995

Prepared for  
U.S. ARMY ENVIRONMENTAL CENTER  
SFIM-AEC-ET-CR-94071

Approved for public release; distribution is unlimited.

## PREFACE

This report was prepared by Thomas A. Ranney, Staff Scientist, Science and Technology Corporation, Hanover, New Hampshire, and Louise V. Parker, Research Physical Scientist, Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire. Funding for this work was provided by the U.S. Army Environmental Center (AEC), Aberdeen Proving Ground, Maryland, Martin H. Stutz, Project Monitor.

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## Susceptibility of ABS, FEP, FRE, FRP, PTFE, and PVC Well Casings to Degradation by Chemicals

THOMAS A. RANNEY AND LOUISE V. PARKER

### INTRODUCTION

Ideally, any material used as either a well casing or a screen in a groundwater monitoring well should retain sufficient strength once installed in the well, should resist degradation by the environment, and should not affect contaminant concentrations in samples by leaching or sorbing organics or metals. Recent guidance by the U.S. Environmental Protection Agency (U.S. EPA 1992) acknowledges that none of the most commonly used well casing materials in groundwater monitoring (polytetrafluoroethylene [PTFE], polyvinyl chloride [PVC], or stainless steel) can be used for all monitoring applications. Strength considerations limit the depth to which PTFE, and to a lesser extent PVC, can be used. The maximum depth PTFE can be used is 225 to 375 ft (69 to 114 m), while the maximum depth PVC can be used is 1200 to 2000 ft (366 to 610 m). While PTFE is very inert to degradation by chemicals (App. A, B), PVC is degraded by several neat organic solvents, including low molecular weight ketones, aldehydes, amines, and chlorinated alkanes and alkenes (Barcelona et al. 1984). (See App. A and B for specific chemicals.) PVC can also be degraded by high concentrations (near solubility) of these organic chemicals in aqueous solution (Berens 1985, Vonk 1985, 1986). Stainless steel will rust if corrosive conditions exist. These include a pH <7.0, a dissolved oxygen content >2 ppm, H<sub>2</sub>S levels ≥1 ppm, total dissolved solids content >1000 ppm, CO<sub>2</sub> levels >50 ppm, and Cl<sup>-</sup> concentrations >500 ppm (Aller et al. 1989, modified from Driscoll 1986). (Additional information on the susceptibility of stainless steel 304 and 316 to a wide range of chemicals can be found in the Cole-Parmer catalog [Cole-Parmer 1992] or in our

previous report [Ranney and Parker 1994]). Also, previous studies by this laboratory (Hewitt 1989, 1992, 1993, Parker et al. 1990, Ranney and Parker 1994) and others (Reynolds and Gillham 1985, Gillham and O'Hannesin 1990, Reynolds et al. 1990) have shown that none of these materials are chemically inert with respect to sorption and leaching of analytes of interest. In these studies, PVC and PTFE sorbed organics, and PVC and SS sorbed and leached metals.

Recently we started a series of laboratory studies to determine the overall suitability of four other pipe and casing materials (acrylonitrile butadiene styrene [ABS], fluorinated ethylene propylene [FEP], fiberglass-reinforced epoxy [FRE], and fiberglass-reinforced plastic [FRP]) for groundwater monitoring applications. In the first study we (Ranney and Parker 1994) compared sorption of a suite of dilute organic solutes by these four materials, along with PVC and PTFE. We found that ABS sorbed organic contaminants much more rapidly and to a greater extent than the other five materials; losses ranged from 19 to 74% after only eight hours. On the other hand, FRE and PVC were relatively nonsorptive, and by the end of the study (6 weeks) losses were no greater than 25%. FEP, FRP, and PTFE were intermediate in their performance, and none of these materials performed consistently better than the other.

We also found that ABS, FRP, and FRE leached contaminants into the test solution. These contaminants were observed as spurious peaks in the HPLC analyses. FRE leached one contaminant while FRP and ABS leached several contaminants (five and eleven, respectively). Several of these peaks were identified by purge and trap GC/MS analyses. With respect to leaching, our results agree well with those of Cowgill (1988) for FRE

and Barcelona et al. (1985) and Curran and Tomson (1983) for PTFE. Presumably FEP would perform similarly to PTFE.

We concluded that FRE looked like the most promising material for monitoring organics and that ABS should not be used when monitoring organics. However, any material that is going to be used for monitoring organic contaminants should also be relatively resistant to degradation by a wide range of organic compounds and should ideally be able to withstand acidic and alkaline environments. This study compares the susceptibility of ABS, FEP, FRE, FRP, PVC, and PTFE to degradation by organic solvents and extremely acidic and alkaline conditions.

## LITERATURE REVIEW

Information on the ability of these materials to resist chemical degradation is sketchy. Most of the information we found was either provided by the manufacturer or taken from the Cole-Parmer catalog (1992) or the Nalge catalog (1994). FEP is a copolymer of tetrafluoroethylene and hexafluoropropylene, and like other fluoropolymers, such

as PTFE, it has excellent resistance to chemical attack by corrosive reagents and dissolution by solvents (Nalge 1994) (App. B). FRE is composed of 75% silica glass and 25% closed molecular epoxy, and according to its manufacturer is impervious to gasoline, hydrocarbon products, and most solvents and additives. The Cole-Parmer catalog (1992) appears to support this claim for hydrocarbons but not for all solvents. They report that "epoxy" has good resistance to fuel oils, gasoline, jet fuel, and kerosene. However, they also report that epoxy is moderately affected by several ketones and is severely degraded by dichloroethane, dimethyl formamide, benzaldehyde, and others. (See App. A for a more extensive listing.) ABS is a terpolymer of acrylonitrile, butadiene, and styrene. According to the Cole-Parmer catalog (1992), it is severely degraded by a number of organic chemicals, including several ketones, chlorinated alkanes and alkenes, and several hydrocarbons such as fuel oils, gasoline, and kerosene. (See App. A for a more extensive listing.) However, it is important to note that the Cole-Parmer catalog does not give any detail on the type of epoxy or ABS materials that were tested.

FRP is composed of 70% fiberglass and 30%

Table 1. Chemicals used in testing polymeric materials for weight gain and degradation (swelling/softening, dissolution).

<i>Hydrocarbons (aliphatic &amp; aromatic)</i>	
Benzene	Kerosene (K-1)
Gasoline (93 octane, unleaded)	Toluene
Hexane (85% N-hexane)	o-xylene
<i>Chlorinated solvents (aliphatic &amp; aromatic)</i>	
Bromochloromethane	1,2-dichloroethane
Carbon tetrachloride	trans-1,2-dichloroethylene
Chlorobenzene	Methylene chloride
Chloroform	Tetrachloroethylene
1,2-dichlorobenzene	Trichloroethylene
<i>Oxygen-containing compounds (either a ketone, alcohol, aldehyde, or ether)</i>	
Acetone	Methyl alcohol
Benzaldehyde	Methyl ethyl ketone
Benzyl alcohol	Tetrahydrofuran
Cyclohexanone	
<i>Nitrogen-containing compounds</i>	
N-butylamine	Dimethylformamide
Diethylamine	Nitrobenzene
<i>Acids and bases</i>	
Acetic acid (glacial)	Sodium hydroxide (25% w/v)
Hydrochloric acid (25% w/v)	

polyester resin. Its manufacturer claims that this product is resistant to corrosion but makes no claims about its resistance to organic solvents. Since the manufacturer did not specify which particular polyester was used in its product, we cannot discuss its chemical resistance except in generic terms. According to Sax and Lewis (1987), polyesters are resistant to corrosive chemicals and solvents. However, Fuchs (1989) listed at least one organic compound that was a good solvent for each of the polyesters he listed.

Thus, among ABS, FEP and FRE, FEP appears to be the most resistant polymer to degradation while ABS is the least resistant.

## MATERIALS AND METHODS

Six types of 5-cm- (2-in.-) diameter well casing or pipe were used in this study: PVC, PTFE, FEP, ABS, FRE, and FRP. For PVC, PTFE, FRP, and FRE, we used well casings manufactured specifically for groundwater monitoring. We were un-

able to find a manufacturer that made FEP well casings but did find one that made "pipe for sampling groundwater." When we tried to purchase the ABS well casing, we found that these manufacturers had gone out of business so we purchased waste and vent pipe. Test specimens measuring approximately 1 cm<sup>2</sup> were cut from each pipe material. Special care was taken to eliminate contamination from grease or oil during the cutting process. We noted that the cutting process fractured some of the specimen edges of the two fiberglass materials and were careful not to use any specimens with fractured edges. All the test pieces were placed in 2% solutions of detergent (Liquinox) and deionized water and stirred for five minutes, then rinsed repeatedly with deionized water until there was no evidence of sudsing. The pieces were drained and rinsed with several additional volumes of deionized water, drained, and then left on paper towels to air dry.

Each test specimen was weighed to  $\pm 0.0001$  and placed in a 22-mL borosilicate glass vial.

Table 2. Percentage weight gain of PTFE exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	0.0	0.1	0.2	0.2	0.2	0.3	0.4
Acetone	0.0	0.1	0.1	0.1	0.2	0.2	0.3
Benzaldehyde	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzene	0.0	0.1	0.1	0.2	0.2	0.2	0.4
Benzyl alcohol	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bromochloromethane	0.0	0.2	0.3	0.4	0.4	0.6	0.7
N-butylamine	0.0	0.0	0.1	0.1	0.1	0.1	0.2
Carbon tetrachloride	0.0	0.1	0.2	0.2	0.3	0.4	0.6
Chlorobenzene	0.0	0.1	0.0	0.1	0.1	0.2	0.3
Chloroform	0.1	0.3	0.4	0.5	0.6	0.8	1.0
Cyclohexanone	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2-dichlorobenzene	0.0	0.1	0.1	0.1	0.1	0.1	0.2
1,2-dichloroethane	0.0	0.1	0.3	0.2	0.2	0.3	0.4
trans-1,2-dichloroethylene	0.3	0.8	1.1	1.2	1.3	1.4	1.4
Diethylamine	0.0	0.1	0.1	0.1	0.2	0.3	0.5
Dimethylformamide	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Gasoline (93 octane, unleaded)	0.0	0.1	0.1	0.1	0.1	0.2	0.3
Hexane (85% N-hexane)	0.0	0.1	0.2	0.2	0.2	0.3	0.4
Hydrochloric acid (25% w/v)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerosene (K-1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Methyl alcohol	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Methyl ethyl ketone	0.0	0.1	0.1	0.1	0.1	0.2	0.3
Methylene chloride	0.1	0.4	0.5	0.6	0.7	0.9	0.9
Nitrobenzene	0.1	0.1	0.1	0.0	0.1	0.1	0.1
Sodium hydroxide (25% w/v)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tetrachloroethylene	0.0	0.2	0.2	0.4	0.4	0.6	0.9
Tetrahydrofuran	0.0	0.1	0.1	0.1	0.2	0.2	0.3
Toluene	0.0	0.0	0.1	0.1	0.1	0.2	0.2
Trichloroethylene	0.1	0.4	0.5	0.7	0.8	1.0	1.3
<i>o</i> -xylene	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Table 3. Percentage weight gain of FEP exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	0.0	0.1	0.1	0.1	0.2	0.2	0.3
Acetone	0.0	0.1	0.1	0.1	0.2	0.2	0.2
Benzaldehyde	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Benzene	0.1	0.1	0.1	0.2	0.1	0.2	0.3
Benzyl alcohol	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Bromochloromethane	0.0	0.1	0.1	0.3	0.3	0.4	0.6
N-butylamine	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Carbon tetrachloride	0.0	0.1	0.1	0.2	0.2	0.4	0.4
Chlorobenzene	0.0	0.1	0.1	0.1	0.1	0.2	0.3
Chloroform	0.1	0.2	0.3	0.4	0.5	0.6	0.8
Cyclohexanone	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1,2-dichlorobenzene	0.0	0.1	0.1	0.1	0.1	0.1	0.1
1,2-dichloroethane	0.0	0.1	0.2	0.1	0.2	0.3	0.3
trans-1,2-dichloroethylene	0.3	0.7	0.9	1.0	1.1	1.2	1.2
Diethylamine	0.0	0.0	0.0	0.0	0.1	0.2	0.3
Dimethylformamide	0.0	0.1	0.1	0.0	0.1	0.0	0.1
Gasoline (93 octane, unleaded)	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Hexane (85% N-hexane)	0.0	0.1	0.1	0.1	0.1	0.2	0.2
Hydrochloric acid (25% w/v)	0.0	0.0	0.0	0.0	-0.1	0.1	0.0
Kerosene (K-1)	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Methyl alcohol	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Methyl ethyl ketone	0.0	0.1	0.1	0.1	0.1	0.1	0.2
Methylene chloride	0.1	0.4	0.4	0.5	0.5	0.7	0.8
Nitrobenzene	0.1	0.0	0.1	0.0	0.1	0.0	0.0
Sodium hydroxide (25% w/v)	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Tetrachloroethylene	0.0	0.1	0.2	0.2	0.3	0.4	0.6
Tetrahydrofuran	0.0	0.0	0.1	0.1	0.1	0.1	0.3
Toluene	0.0	0.1	0.1	0.1	0.1	0.2	0.2
Trichloroethylene	0.2	0.4	0.3	0.5	0.6	0.8	1.1
o-xylene	0.0	0.0	0.1	0.0	0.0	0.0	0.1

Twenty-eight neat organic compounds (including one acid), and 25% solutions of hydrochloric acid and sodium hydroxide (Table 1) were used in this study. Twenty-seven neat organic solvents were tested, including six hydrocarbons (aliphatic and aromatic), ten chlorinated solvents (aliphatic and aromatic), seven oxygen-containing compounds (that were either a ketone, alcohol, aldehyde, or ether), and four nitrogen-containing compounds. Most of the test compounds were EPA priority pollutants. Five mL of the test chemical were added to a vial and the vial was sealed with a Teflon-lined, plastic cap. There were no replicate samples in this study. There were seven sampling times: 1, 7, 14, 21, 28, 56, and 112 days. On each sampling day, each test coupon was removed from the vial using stainless steel forceps, blotted with a paper towel and allowed to air dry for approximately one minute before weighing (to  $\pm 0.0001$ ). Weight gain or loss was used as one measure of physical change. Softening was deter-

mined by seeing if the specimen could be easily indented with the forceps using an untreated piece of material as a reference. After weighing, the specimen was returned to its vial and the vial was recapped. Test samples were stored at room temperature.

## RESULTS AND DISCUSSION

Tables 2-7 show the percentage weight gains for the six materials and any other observations relative to physical degradation (swelling, softening, decrease in strength, deterioration, and dissolution).

Although PTFE and FEP are generally recognized as being inert to degradation by chemicals, by the end of the study they did show slight weight gains (~1%) when exposed to five organic chemicals (chloroform, trans-1,2-dichloroethylene, methylene chloride, tetrachloroethylene, and tri-

Table 4. Percentage weight gain of FRE exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	0.9	2.3*	3.1	3.6	3.6	F	
Acetone	0.6	1.8	1.8	1.9	2.0	2.2	2.7
Benzaldehyde	0.1	0.1	0.5	0.4	0.3	0.2	0.3
Benzene	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benzyl alcohol	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Bromochloromethane	6.2	11.4	20.8	23.5	24.1	25.6	26.2
N-butylamine	1.5	*F					
Carbon tetrachloride	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Chlorobenzene	0.3	0.3	0.3	0.2	0.1	0.1	0.2
Chloroform	0.3	1.8	4.9	4.7	5.5	6.2	7.3
Cyclohexanone	0.0	0.0	0.7	-0.1	-0.1	-0.1	-0.1
1,2-dichlorobenzene	0.1	0.1	0.0	0.1	0.1	0.1	0.1
1,2-dichloroethane	0.1	0.4	1.3	2.1	2.7	2.8	3.1
trans-1,2-dichloroethylene	0.0	0.4	0.7	1.2	2.4	4.6	8.1
Diethylamine	0.2	1.8	2.0	1.9	2.0	2.0	2.0
Dimethylformamide	1.8	3.0*	F				
Gasoline (93 octane, unleaded)	0.0	0.0	0.1	-0.1	-0.1	-0.1	-0.1
Hexane (85% N-hexane)	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1
Hydrochloric acid (25% w/v)	0.1	0.3	0.1	-0.2	-0.4	-1.9	-4.7
Kerosene (K-1)	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Methyl alcohol	0.5	1.8	2.9	3.2	3.9	5.2	7.7
Methyl ethyl ketone	0.2	1.3	2.2	2.4	2.4	2.6	3.0
Methylene chloride	4.3	9.7	14.4	15.0	15.4	15.3	15.6
Nitrobenzene	0.3	0.5	0.6	0.5	0.3	0.5	0.4
Sodium hydroxide (25% w/v)	0.1	0.2	0.2	0.0	0.2	0.2	0.2
Tetrachloroethylene	0.0	0.0	0.1	-0.1	0.0	0.0	0.0
Tetrahydrofuran	0.2	0.7	1.6	2.2	2.6	3.1	3.3
Toluene	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
Trichloroethylene	0.1	0.2	0.2	0.2	0.2	0.3	0.3
o-xylene	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1

\* particles began to flake off coupon

F fibers separated

chloroethylene) (Tables 2, 3). The weight gains were slightly less for FEP than PTFE. We did not observe any softening, swelling, or decrease in strength in any of these samples when compared with unexposed test pieces. For reference, the final pH of the 25% HCl solution containing the PTFE samples was -0.75 and the final pH of the 25% NaOH solution containing the PTFE samples was 13.4.

The FRE well casing material used in this study had a glossy external surface and a dull (frosted) internal surface. Three organic chemicals (acetic acid, N-butylamine, and dimethylformamide) caused some flaking of the external surface within the first week and separation of the glass fibers after one to eight weeks. N-butylamine delaminated FRE after five weeks. The particles that flaked off the test pieces did not appear to dissolve with time. No further weight

measurements were made on these samples. Eight other samples had weight gains of 1 to 10%, and samples exposed to bromochloromethane (26.2%) and methylene chloride (15.6%) had the largest weight gains (Table 4). The sample exposed to the hydrochloric acid solution lost weight (~5%), most likely a result of loss of the epoxy resin. The alkaline solution had no effect on this material. None of the FRE specimens appeared to swell or soften, not even the samples with the largest weight gain. Some fraying of the edges was observed on some specimens, but it is not clear whether this was due to chemical exposure, cutting, or handling. In general, FRE did not appear to be affected by the hydrocarbons or aromatic solvents.

FRP was more severely degraded than the previous materials. Eight organic solvents (bromochloromethane, N-butylamine, chloroform, 1,2-

Table 5. Percentage weight gain of FRP exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	0.3	0.2	0.3	0.6	0.7	0.9	1.5
Acetone	0.2	2.5	5.0	5.5	5.6	5.6	5.6
Benzaldehyde	0.5	0.5	0.8	0.7	0.7	0.8	1.3
Benzene	0.0	0.1	0.2	0.2	0.3	0.4	0.8
Benzyl alcohol	0.4	0.3	0.5	0.3	0.4	0.4	0.5
Bromochloromethane	21.2	L					
N-butylamine	-0.2	0.3	1.3	L			
Carbon tetrachloride	0.1	0.1	0.1	0.2	0.1	0.1	0.2
Chlorobenzene	0.7	0.8	1.5	2.1	2.8	4.5	7.8
Chloroform	6.5	L					
Cyclohexanone	0.2	0.2	1.1	0.3	0.6	0.5	0.1
1,2-dichlorobenzene	0.6	0.7	0.7	0.8	0.8	1.0	1.1
1,2-dichloroethane	1.0	14.0	14.6	L			
trans-1,2-dichloroethylene	7.6	11.2	L				
Diethylamine	0.0	0.1	0.4	0.4	0.8	1.9	3.5
Dimethylformamide	0.3	1.1	2.3	4.4	6.2	8.7	8.3
Gasoline (93 octane, unleaded)	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Hexane (85% N-hexane)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrochloric acid (25% w/v)	0.1	0.1	-0.2	-0.4	-0.7	-1.8	-5.0
Kerosene (K-1)	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Methyl alcohol	0.2	0.6	0.9	0.9	1.1	1.5	1.9
Methyl ethyl ketone	0.1	1.5	3.6	4.6	4.9	4.8	4.8
Methylene chloride	L						
Nitrobenzene	0.7	0.9	0.8	0.7	0.7	0.8	1.0
Sodium hydroxide (25% w/v)	0.0	0.1	-0.1	-0.2	-0.2	0.4	1.5
Tetrachloroethylene	0.1	0.2	0.3	0.2	0.3	0.4	0.5
Tetrahydrofuran	0.3	2.5	6.9	9.9	L		
Toluene	0.1	0.2	0.2	0.3	0.3	0.5	0.9
Trichloroethylene	0.8	7.9	16.7	16.3	L		
<i>o</i> -xylene	0.0	0.1	0.1	0.0	0.1	0.2	0.2

L glass fiber sheets separated

dichloroethane, *trans*-1,2-dichloroethylene, methylene chloride, tetrahydrofuran, and trichloroethylene) delaminated it, i.e., the fiberglass sheets separated. This occurred within the first 24 hours for methylene chloride and within the first one to four weeks for the other solvents. The samples that were delaminated more slowly had weight gains of -1 to 16% and showed signs of swelling (i.e., liquid could be squeezed out of the material) prior to the sheets separating. Eleven other chemicals (including the glacial acetic acid and the sodium hydroxide solution) caused weight gains of 1 to 10% (Table 5). None of these chemicals caused any noticeable swelling or softening. Again, some of the specimens showed frayed edges, although this may have resulted from cutting or handling and not chemical exposure. As with FRE, the hydrochloric acid solution caused a slight loss in weight (5%). FRP appeared to be unaffected by hydrocarbons and the nonpolar chlorinated solvents.

PVC appeared to be much more readily degraded than the previous materials. By the end of the study, ten chemicals dissolved or so softened PVC that the test piece could not be weighed because it disintegrated (Table 6). Four chemicals had this effect within the first day. Ten other chemicals appeared to soften PVC and four of those chemicals caused weight gains that exceeded 100%. Squeezing the swollen specimens forced out some of the liquid. Only nine of the thirty chemicals used in this study had little or no effect on PVC. These chemicals were the neat acid, the acid and hydroxide solutions, the two alcohols, three hydrocarbons (gasoline, hexane, and kerosene) and carbon tetrachloride. In general, PVC is especially susceptible to degradation by polar, non-hydrogen-bonded solvents.\*

\* Personal communication, Daniel C. Leggett, Research Chemist, CRREL, 1994.

Table 6. Percentage weight gain of PVC exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	0.1	0.1	0.2	0.2	0.3	0.2	0.4
Acetone	142.6 <sup>s</sup>	145.5	146.7	151.4	156.4	157.3	157.8
Benzaldehyde	100.9 <sup>s</sup>	D					
Benzene	7.2	29.7 <sup>s</sup>	45.4	49.5	49.2	48.8	48.7
Benzyl alcohol	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Bromochloromethane	D						
N-butylamine	63.8 <sup>s</sup>	111.0	110.7	D			
Carbon tetrachloride	0.0	0.1	0.0	0.1	0.1	0.1	0.1
Chlorobenzene	57.2 <sup>s</sup>	151.1	153.0	156.6	157.3	158.8	159.8
Chloroform	144.2 <sup>s</sup>	216.1	218.2	221.9	220.3	222.8	223.9
Cyclohexanone	D						
1,2-dichlorobenzene	16.8 <sup>s</sup>	73.5	134.3	206.6	208.6	214.5	217.7
1,2-dichloroethane	206.6 <sup>s</sup>	352.4	D				
trans-1,2-dichloroethylene	49.6 <sup>s</sup>	57.7	57.5	56.2	56.2	56.0	56.3
Diethylamine	2.5	8.7	13.8	17.2	20.4	23.9	31.8 <sup>s</sup>
Dimethylformamide	D						
Gasoline (93 octane, unleaded)	0.0	0.0	0.2	0.0	0.0	0.0	0.1
Hexane (85% N-hexane)	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Hydrochloric acid (25% w/v)	0.2	0.2	0.1	0.1	0.0	0.1	0.3
Kerosene (K-1)	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Methyl alcohol	0.4	0.1	0.2	0.2	0.2	0.3	0.4
Methyl ethyl ketone	298.9 <sup>s</sup>	D					
Methylene chloride	454.9 <sup>s</sup>	D					
Nitrobenzene	138.1 <sup>s</sup>	D					
Sodium hydroxide (25% w/v)	0.0	0.0	0.1	0.2	0.1	0.1	0.1
Tetrachloroethylene	0.1	0.4	0.6	0.7	0.8	1.2	1.7
Tetrahydrofuran	D						
Toluene	10.5	38.4 <sup>s</sup>	51.6	50.9	50.7	50.6	51.4
Trichloroethylene	34.9 <sup>s</sup>	71.3	72.8	70.1	71.0	70.5	70.9
o-xylene	3.8	11.7 <sup>s</sup>	17.1	23.0	28.2	44.4	65.7

D dissolved or disintegrated upon handling

s first observation of swelling and/or softening

ABS was by far the most readily degraded polymer. After only one day, nineteen of the thirty chemicals tested either dissolved ABS or softened it to the point where it fell apart (Table 7). Four other chemicals caused either softening or swelling of the test coupon on the first day. By the end of the study, only the acid and alkali solutions had little effect (~1% weight gain). While ABS is susceptible to organic solvents in general, it is especially susceptible to polar solvents.\* Clearly, ABS is a poor choice where exposure to neat organic solvents may be involved.

Table 8 compares the chemical resistance ratings from the Cole-Parmer catalog and the Nalge catalog with our (CRREL) findings. In order to compare our results with the chemical resistance

ratings given by Cole-Parmer and Nalge companies, we developed the following classification scheme for our data:

A. *Excellent*. Any chemical that had little or no effect on the material, i.e., where the change in weight was 1% or less.

B. *Good*. Any chemical that had only a minor effect, i.e., there was no observable effect except for a slight change in weight (from 1 to 5%).

C. *Moderate effect*. Those chemicals that caused more than a 5% change in weight with no other observable changes.

D. *Unacceptable*. Any chemical that caused the material to swell, soften, dissolve, delaminate, or that caused particles to fall off.

While we realize that our rating system was totally arbitrary, we generally had good agreement between our results and those given in the Cole-Parmer catalog. This was especially true for PTFE and ABS. For these materials there were

\* Personal communication, Daniel C. Leggett, Research Chemist, CRREL, 1994.



Table 7. Percentage weight gain of ABS exposed to chemical treatment.

Chemical	Contact time (days)						
	1	7	14	21	28	56	112
Acetic acid (glacial)	19.9	46.6 <sup>s</sup>	55.9	61.1	64.0	70.7	76.8
Acetone	D						
Benzaldehyde	D						
Benzene	D						
Benzyl alcohol	D						
Bromochloromethane	D						
N-butylamine	D						
Carbon tetrachloride	80.6 <sup>s</sup>	260.1	269.9	290.5	291.2	303.3	317.2
Chlorobenzene	D						
Chloroform	D						
Cyclohexanone	D						
1,2-dichlorobenzene	D						
1,2-dichloroethane	D						
trans-1,2-dichloroethylene	D						
Diethylamine	83.0 <sup>s</sup>	110.8	112.9	105.5	108.6	110.6	112.8
Dimethylformamide	D						
Gasoline (93 octane, unleaded)	20.6	50.0 <sup>s</sup>	56.6	58.4	58.7	60.9	61.9
Hexane (85% N-hexane)	1.5	5.8	8.7	9.9	11.2	13.4	15.1
Hydrochloric acid (25% w/v)	0.1	0.5	0.5	0.6	0.6	0.9	1.2
Kerosene (K-1)	0.5	1.4	2.0	2.7	3.3	5.6	8.9
Methyl alcohol	4.2	10.0	13.0	15.0	16.5	21.8	27.8
Methyl ethyl ketone	D						
Methylene chloride	D						
Nitrobenzene	D						
Sodium hydroxide (25% w/v)	0.4	0.8	0.8	0.7	0.8	0.7	0.9
Tetrachloromethylene	102.9 <sup>s</sup>	211.2	232.7	237.2	236.9	245.7	251.2
Tetrahydrofuran	D						
Toluene	D						
Trichloromethylene	D						
o-xylene	206.2 <sup>s</sup>	D					

D dissolved or disintegrated upon handling

s first observation of swelling and/or softening

only five or six chemicals (respectively) where the ratings did not agree (given in bold print in Table 8). (There were no listings for FEP or FRP.) The largest disparity is between their ratings for "epoxy" and our findings for FRE. For FRE, we would change the ratings for 17 of the 30 chemicals tested, although there is no trend in either direction. The differences between "epoxy" and FRE most likely account for these differences. Differences in contact time may also explain some of these differences. For PVC we would change the ratings for seven chemicals, raising it for six of them.

Generally, our results agreed with those of the Nalge Company for PTFE, FEP, and rigid PVC. There were exceptions for two chemicals (TCE and chloroform) for PTFE and one exception for FEP (TCE). For rigid PVC there were six chemicals where our results did not agree; we would raise the rating for four of those chemicals.

## CONCLUSIONS AND RECOMMENDATIONS

Based on our findings, we would rank the resistance of these materials to organic solvents, from greatest to least resistance, as: FEP=PTFE>FRE>FRP>PVC>ABS. This ranking should be used only as a general guide, not as a rule. FRE, FRP, ABS, and PVC casing materials should be tested with any chemical they are going to be exposed to, if they haven't been already. It appears that all the materials have excellent resistance to alkaline conditions except FRP, which was only slightly affected. With respect to exposure to acidic conditions, FEP, PTFE, and PVC all have excellent resistance, ABS was slightly affected, and FRE and FRP were affected the most, although weight losses were only 5% by the end of the study.

Table 8. Comparison of CRREL chemical resistance ratings with those given in Cole-Parmer and Nalge catalogs.

Chemical	PTFE			FEP		FRE		PVC				ABS	
	C-P*	CRREL	Nalge†	CRREL	Nalge	C-P "epoxy"	CRREL	C-P	CRREL	Nalge rigid	Nalge flexible	C-P	CRREL
Acetic acid (glacial)	A	A		A		C	D	D	A			D	D
Acetone	A	A	E	A	E	B1	B	D	D	N	N	D	D
Benzaldehyde	A1	A	E	A	E	D	A	D	D	N	N	B	D
Benzene	A	A	E	A	E	C1	A	C1	D	N	N	D	D
Benzyl alcohol	A	A	E	A	E	C	A	D	A	G	F	D	D
Bromochloromethane	A	A		A			C		D				D
N-butylamine	A2	A		A		B2	D	D	D				D
Carbon tetrachloride	A	A	E	A	E	A1	A	D	A	G	N	D	D
Chlorobenzene	B	A	E	A	E	C1	A	D	D	N	N	D	D
Chloroform	A1	B	E	A	E	C1	C	D	D	N	N	D	D
Cyclohexanone	A	A	E	A	E	C	A	D	D	N	N	D	D
1,2-dichlorobenzene	A	A	E	A	E	A	A	D	D	N	N	D	D
1,2-dichloroethane	A1	A	E	A	E	D	B	D	D	F	N	D	D
trans-1,2-dichloroethylene		B		B			C		D				D
Diethylamine	D	A	E	A	E	A	B	D	D	N	N	D	D
Dimethylformamide	D	A	E	A	E	D	D	D	D	F	N	D	D
Gasoline (93 octane, unleaded)	A	A	E	A	E	A2	A	C2	A	G	N	D	D
Hexane	A	A	E	A	E	A	A	B2	A	G	N	D	C
Hydrochloric acid (25% w/v)	A	A	E	A	E	A1	B	A2	A	E	E	A	B
Kerosene (K-1)	A	A	E	A	E	A	A	A2	A	E	N	D	C
Methyl alcohol	A	A	E	A	E	B1	C	A1	A	E	F	D	C
Methyl ethyl ketone	A	A	E	A	E	C1	B	D	D	N	N	D	D
Methylene chloride	A	A	E	A	E	A	C	D	D	N	N	D	D
Nitrobenzene	A	A	E	A	E	C1	A	D	D	N	N	D	D
Sodium hydroxide (25% w/v)	A	A		A		A	A	A	A			B	A
Tetrachloroethylene	A	A		A			A	D	B				D
Tetrahydrofuran	A	A	E	A	E	A	B	D	D	N	N		D
Toluene	A	A	E	A	E	B1	A	D	D	N	N	D	D
Trichloroethylene	A	B	E	B	E	C1	A	D	D	N	N	D	D
o-xylene	A	A	E	A	E	A	A	D	D	N	N	D	D

## \* Cole-Parmer chemical resistance ratings

- A no effect-excellent  
 B minor effect-good  
 C moderate effect-fair  
 D severe effect-not recommended  
 1 satisfactory to 22°C  
 2 satisfactory to 48°C

## † Nalge chemical resistance ratings (20°C)

- E no damage after 30 days  
 G little or no damage after 30 days  
 F some effect after 7 days  
 N not recommended for continuous use

## CRREL chemical resistance ratings from experimental observations

- A Excellent. Any chemical with little or no effect, i.e., the change in weight was 1% or less.  
 B Good. Any chemical that had only a minor effect, i.e., there was no observable effect except for a slight change in weight (from 1 to 5%).  
 C Moderate effect. Those chemicals that caused more than a 5% change in weight with no other observable changes.  
 D Unacceptable. Any chemical that caused the material to swell, soften, dissolve, delaminate, or lose particles.

Based on our findings and those in other studies (Cowgill 1988, Ranney and Parker 1994), we feel that FRE appears to make an excellent candidate material for monitoring organics. It is relatively nonsorptive of dissolved organic solutes (Ranney and Parker 1994) and is more resistant to degradation by solvents than the more commonly used PVC. Also, our previous study (Ranney and Parker 1994) and that of Cowgill (1988) show that FRE does not leach many organic contaminants that would interfere with analyses. However, because we found that strongly acidic conditions (pH <1) degraded this polymer, its use in acidic environments may be limited. Further tests are needed to resolve this issue.

In this study and our previous study (Ranney and Parker 1994), FEP performed similarly to PTFE. These polymers are very resistant to degradation by chemicals, do not appear to leach organic contaminants, but are quite sorptive of some organic solutes. FEP does not appear to offer any clear advantage or disadvantage over PTFE.

The chemical resistance of FRP is similar to that of PVC except that, unlike PVC, it is degraded by very acidic conditions. FRP is much more sorptive of dilute organic solutes than PVC and has been found to leach organic contaminants (Ranney and Parker 1994). Therefore, we feel that PTFE, FEP, FRE and PVC would be generally better for monitoring organics than FRP.

Our previous study (Ranney and Parker 1994) has shown that PVC is relatively nonsorptive of dilute organic solutes and does not leach organic contaminants. However, PVC cannot be used when neat PVC solvents are present or high concentrations of these solvents are present. (This issue has been addressed by our laboratory in several papers [Parker 1992, Parker et al. 1992, Parker and Ranney 1994a,b].) However, it should be noted that neat organic (PVC) solvents are not normally encountered in most groundwater monitoring situations. High concentrations of organic (PVC) solvents (approaching their aqueous solubility) are also relatively uncommon. Thus PVC can be used in most groundwater monitoring applications.

Of the six casing materials we have tested, we feel that ABS would be the worst material for monitoring organic contaminants. It was affected or degraded by all of the organic solvents we tested. It also leached many organic contaminants and was extremely sorptive of dilute organic solutes (Ranney and Parker 1994).

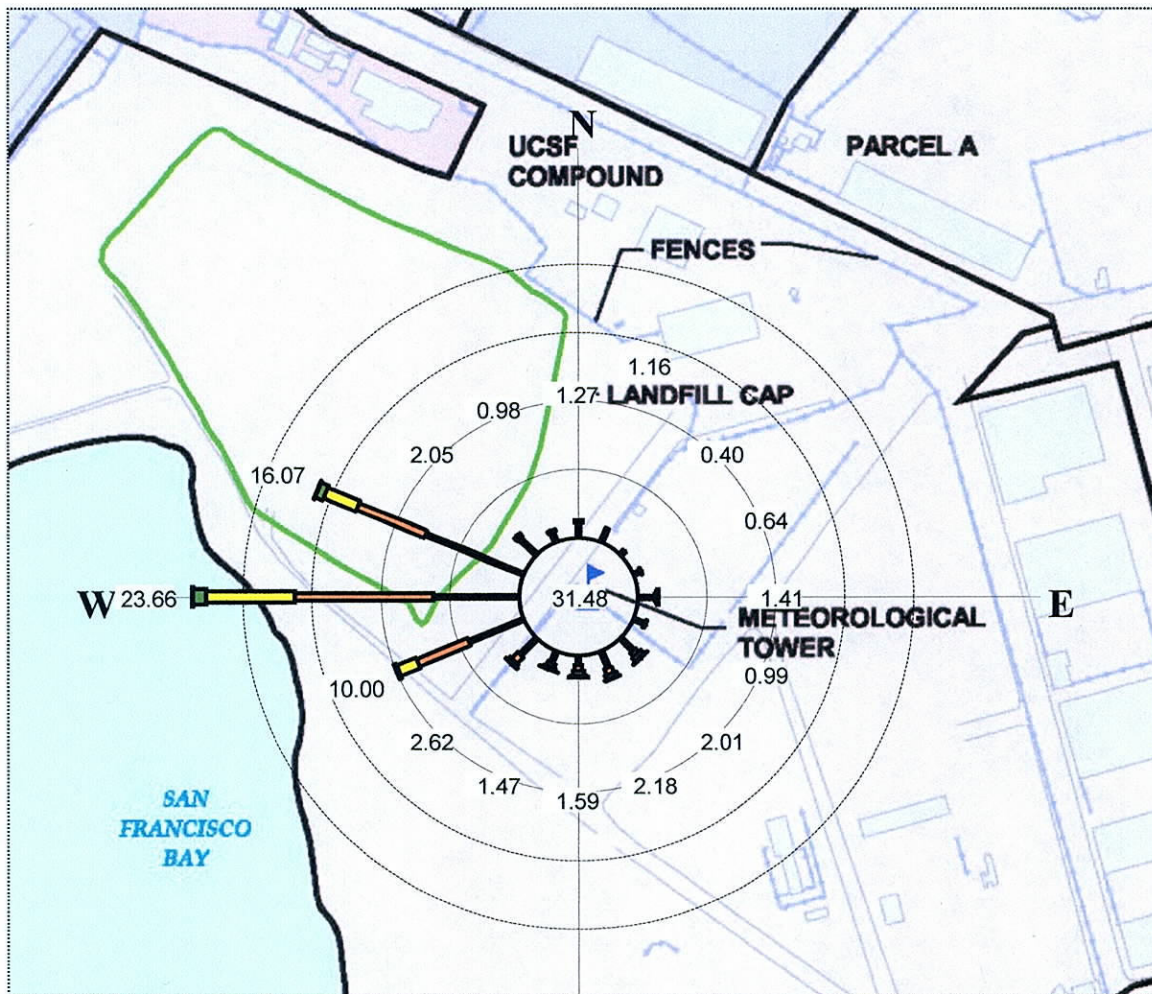
We are currently testing FRE, FEP, and FRP to determine whether they sorb or leach metals. This will help us determine the overall suitability of these materials for use in groundwater monitoring wells.

#### LITERATURE CITED

- Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielsen, and J.E. Denne (1989) *Handbook of Suggested Practices for the Design and Installation of Ground-water Monitoring Wells*. Dublin, Ohio: National Water Well Association.
- Barcelona, M.J., J.P. Gibb, and R.A. Miller (1984) A guide to the selection of materials for monitoring well construction and ground water sampling. U.S. Environmental Protection Agency Report No. EPA-600/2-84-024, U.S. Government Printing Office, Washington, D.C.
- Barcelona, M.J., J.A. Helfrich, and E.E. Garske (1985) Sampling tubing effects on ground water samples. *Analytical Chemistry*, 57: 460-464.
- Berens, A.R. (1985) Prediction of organic chemical permeation through PVC pipe. *Journal of the American Water Works Association*, 77(11): 57-64.
- Cole-Parmer Instrument Company (1992) *Cole-Parmer Instrument Company 1993-1994 Catalog*, p. 1463-1471. Niles, Illinois: Cole-Parmer Instrument Company.
- Cowgill, U.M. (1988) The chemical composition of leachate from a two-week dwell-time study of PVC casing and a three-week dwell time study of fiberglass reinforced epoxy well casing. In *Ground-Water Contamination: Field Methods*, ASTM STP 963 (A.G. Collins and A.I. Johnson, Eds.), p. 172-184. Philadelphia, Pennsylvania: American Society for Testing and Materials.
- Curran, C.M. and M.B. Tomson (1983) Leaching of trace organics into water from five common plastics. *Ground Water Monitoring Review*, 3: 68-71.
- Driscoll, F.G. (1986) *Ground Water and Wells*. St. Paul, Minnesota: Johnson Division.
- Fuchs, O. (1989) Solvents and non-solvents for polymers. In *Polymer Handbook, Third Edition* (J. Brandrup and E.H. Immergut, Eds.). New York: John Wiley and Sons, Inc.
- Gillham, R.W. and S.F. O'Hannesin (1990) Sorption of aromatic hydrocarbons by materials used in construction of ground-water monitoring sampling wells. In *Ground Water and Vadose Zone Monitoring*, ASTM STP 1053 (D.M. Nielsen and A.I. Johnson, Eds.), p. 108-122. Philadelphia, Penn-

- sylvania: American Society for Testing and Materials.
- Hewitt, A.D. (1989) Leaching of metal pollutants from four well casings used for ground-water monitoring. USA Cold Regions Research and Engineering Laboratory, Special Report 89-32.
- Hewitt, A.D. (1992) Potential of common well casing materials to influence aqueous metal concentrations. *Ground Water Monitoring Review*, 12(2): 131-135.
- Hewitt, A.D. (1993) Dynamic study of common well screen materials. *Ground Water Monitoring and Remediation*, 13(1): 87-94.
- Nalge Company (1994) *Nalge Labware 1994*, p. 202-207. Rochester, New York: Nalge Company.
- Parker, L.V. (1992) Suggested guidelines for the use of PTFE, PVC, and stainless steel in samplers and well casings. In *Current Practices in Ground Water and Vadose Zone Investigations*, ASTM STP 1118 (D.M. Nielsen and M.N. Sara, Eds.), p. 217-229. Philadelphia, Pennsylvania: American Society for Testing and Materials.
- Parker, L.V. and T.A. Ranney (1994a) Softening of rigid PVC by aqueous solutions of organic solvents. USA Cold Regions Research and Engineering Laboratory, Special Report 94-15.
- Parker, L.V. and T.A. Ranney (1994b) Effect of concentration on sorption of dissolved organics by well casings. *Ground Water Monitoring and Remediation*, 14(3): 139-149.
- Parker, L.V., A.D. Hewitt, and T.F. Jenkins (1990) Influence of casing materials on trace-level chemicals in well water. *Ground Water Monitoring Review*, 10(2): 146-156.
- Parker, L.V., T.A. Ranney, and S. Taylor (1992) Softening of rigid polyvinyl chloride by high concentrations of aqueous solutions of methylene chloride. USA Cold Regions Research and Engineering Laboratory, Special Report 92-12.
- Ranney, T.A. and L.V. Parker (1994) Sorption of trace-level organics by ABS, FEP, FRE, and FRP well casings. USA Cold Regions Research and Engineering Laboratory, Special Report 94-15.
- Reynolds, G.W. and R.W. Gillham (1985) Adsorption of halogenated organic compounds by polymer materials commonly used in groundwater monitors. In *Proceedings of Second Canadian/American Conference on Hydrogeology, Hazardous Wastes in Ground Water: A Soluble Dilemma*. National Water Well Association, Dublin, Ohio, p. 125-132.
- Reynolds, G.W., J.T. Hoff, and R.W. Gillham (1990) Sampling bias caused by materials used to monitor halocarbons in groundwater. *Environmental Science and Technology*, 24(1): 135-142.
- Sax, N.I. and R.J. Lewis, Sr. (1987) *Hawley's Condensed Chemical Dictionary, Eleventh Edition*. New York: Van Nostrand Reinhold Company.
- U.S. EPA (1992) *EPA RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001, Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C. 20460. NTIS #PB 93-139-350, National Technical Information Service, Springfield, Virginia 22161 (703-487-4650).
- Vonk, M.W. (1985) Permeatie en Drinkwaterleidingen. KIWA, N.V., Nieuwegein, The Netherlands, KIWA Report 85 (In Dutch with English summary).
- Vonk, M.W. (1986) Permeation of organic soil contaminants through polyethylene, polyvinylchloride, asbestos cement and concrete water pipes. In *Proceedings, American Water Works Association Water Quality Technical Conference, 1985*, vol. 13, p. 701-714.

# **Wind Rose Plot for Parcel E Meteorological Station** **Period of Data Collected: September 17, 2002 To July 22, 2004**



Meteorological station coordinates:  
 122° 22 22 West  
 37° 43 24 North



Wind Speed (Miles Per Hour)

## **Notes:**

The meteorological station records wind speed and wind direction every second; hourly averages are computed and used to generate this wind rose.

Calms included at center.  
 Rings drawn at 5% intervals.  
 Wind flow is FROM the directions shown.  
 No observations were missing.

## **PERCENT OCCURRENCE: Wind Speed (Miles Per Hour)** **LOWER BOUND OF CATEGORY**

DIR	5	10	15	20	25	30
N	1.13	0.14	0.01	0.00	0.00	0.00
NNE	1.16	0.01	0.00	0.00	0.00	0.00
NE	0.40	0.00	0.01	0.00	0.00	0.00
ENE	0.55	0.08	0.01	0.00	0.00	0.00
E	1.18	0.09	0.11	0.03	0.00	0.00
ESE	0.87	0.11	0.01	0.00	0.00	0.00
SE	1.29	0.33	0.31	0.07	0.02	0.00
SSE	1.28	0.51	0.32	0.05	0.01	0.01

TOTAL OBS = 16173 MISSING OBS = 0

## **PERCENT OCCURRENCE: Wind Speed (Miles Per Hour)** **LOWER BOUND OF CATEGORY**

DIR	5	10	15	20	25	30
S	0.69	0.41	0.34	0.10	0.03	0.01
SSW	0.86	0.37	0.15	0.04	0.03	0.01
SW	1.64	0.63	0.25	0.09	0.01	0.00
WSW	4.32	3.98	1.52	0.17	0.01	0.00
W	6.20	9.97	6.48	0.93	0.08	0.01
WNW	7.67	5.31	2.50	0.57	0.02	0.00
NW	1.73	0.32	0.01	0.00	0.00	0.00
NNW	0.79	0.19	0.00	0.00	0.00	0.01

CALM OBS = 5092 PERCENT CALM = 31.48

Percentage rings indicate the percentage of time (1) the wind was blowing from a certain direction and (2) looking at the breakdown of speeds in each bar, the wind was blowing from a certain direction at a certain wind speed. For each direction (or bar), the percentages of each wind speed interval add up to the total time the wind was blowing from that direction, which is indicated by the total length of the bar. The total times for each direction are noted at the end of the bars.





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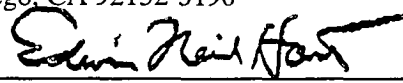
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CTO: 0084  
LOCATION: Hunters Point Shipyard

FROM:

  
Neil Hart, Program Manager

DESCRIPTION: Response to Comments on Draft Final Project Work Plan Revision 0,  
May 27, 2005, PCB Hot Spot Soil Excavation Site Parcels E and E-2, HPS  
and Response to Comments on Field Change Request 035 (FCR-PCBHS-035), September 2005

TYPE: ☐ Contract/Deliverable ☒ CTO Deliverable ☐ Notification  
☐ Other

VERSION: N/A REVISION #: N/A  
(e.g. Draft, Draft Final, Final, etc.)

ADMIN RECORD: Yes ☒ No ☐ Category ☐ Confidential ☐  
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